A COMPOSITE BEAM

The present invention relates to composite beams for the construction industry.

The term "composite beam" is understood herein to mean: (i) a beam, preferably formed from steel, and (ii) a solid slab or a composite slab; that are interconnected by shear connection to act together to resist action effects as a single structural member.

The term "shear connection" is understood herein to mean an interconnection between a beam and a solid slab or a composite slab of a composite beam which enables the two components to act together as a single structural member under the action effect of bending which causes longitudinal shear forces to develop.

In conventional composite beams, typically, the shear connection includes shear connectors, slab concrete, and transverse reinforcement.

The term "shear connector" is understood herein to mean a mechanical device attached to a beam (typically to a top flange of the beam) which forms part of the shear connection.

The present invention relates particularly, although by no means exclusively, to composite beams of the type which include:

(a) a horizontal beam (typically steel) supported at each end;

(b) a composite slab that is positioned on and supported by the beam and includes:

(i) profiled metal (typically steel) sheeting having a plurality of pans separated by ribs, the profiled sheeting being positioned in relation to the beam so that the ribs are parallel to the longitudinal axis of the beam or the ribs and the longitudinal axis of the beam describe an acute angle of less than or equal to 15°;

(ii) concrete cast on the sheeting, with the cast concrete including concrete ribs defined by the pans and sides of adjacent ribs; and

(iii) reinforcement embedded in the cast concrete; and

(c) a plurality of shear connectors, typically in the form of headed studs, embedded in the cast concrete and welded to the beam thereby to connect the composite slab to the beam.

The present invention is concerned with overcoming a major problem that occurs with composite beams of the type described above that include conventional welded stud shear connectors and profiled steel decking having open metal ribs. The problem is a complex type of longitudinal shear failure involving lateral rib punch-through failure that has been studied by the applicant in research work that has been carried out by the applicant. The problem of lateral rib punch-through is not confined to this particular type of composite beam.

An object of the present invention is to provide a composite beam with improved resistance to longitudinal shear failure involving lateral rib punch-through.

According to the present invention there is provided a composite beam which includes:

(a) a beam;

(b) a solid slab or a composite slab positioned on and supported by the beam, the solid slab and the composite slab including a slab section and a plurality of concrete ribs extending from the slab section;

(c) at least one shear connector positioned in at least one of the concrete ribs and connecting the solid slab or the composite slab to the beam; and

(d) a reinforcing component embedded in at least one concrete rib that includes embedded shear connector or connectors, the reinforcing component being in the form of a mesh that includes line wires and cross wires that are connected together at the intersections of the wires.

The applicant has found that the reinforcing component described in sub-paragraph (d) above improves dramatically the resistance to lateral rib punch-through failure of the composite beam.

Preferably the concrete ribs are parallel to the longitudinal axis of the beam or the concrete ribs and the longitudinal axis of the beam describe an acute angle of

less than or equal to 15°.

It is preferred that the mesh be positioned so that the line wires extend in the longitudinal direction of the concrete rib, ie in the longitudinal direction of the beam.

With this arrangement, the purpose of the cross wires is to take tension forces and balance transverse components of shear connector reactive forces that develop in the base region of the shear connector or connectors.

The research work carried out by the applicant indicates that lateral rib punch-through failure of the beam would not be prevented without these cross wires.

One purpose of the line wires is to anchor the cross wires so that the cross wires can take tension forces.

Another purpose of the line wires is to balance the longitudinal components of shear connector reactive forces that develop in the base region of the shear connector or connectors.

It is preferred that the mesh be positioned in the concrete rib between 25% and 75% of the height of the concrete rib.

In a situation in which the composite beam includes a composite slab rather than a solid slab, preferably the composite slab includes profiled metal sheeting having a plurality of metal pans separated by metal ribs and concrete cast on the profiled sheeting. With this arrangement the metal pans and the sides of the metal ribs define the outer surfaces of the concrete ribs.

Preferably the mesh is positioned in the concrete rib below the level of the tops of adjacent ribs of the profiled sheeting.

It is preferred that the mesh be positioned in the concrete rib between 25% and 75% of the height of the adjacent metal ribs.

It is preferred that the mesh extend across the width of the concrete rib at the position of the mesh in the concrete rib.

It is preferred that the reinforcing component further includes a plurality of additional reinforcing elements that extend transverse to the line wires of the mesh and have one or more than one section out of the plane of the mesh.

It is preferred that the additional reinforcing elements be cranked handlebar-shaped elements.

It is preferred that the section or sections of each additional reinforcing element that is out of the plane of the mesh extend from the concrete rib into the slab section of the solid slab on the composite slab.

It is preferred that the beam be a steel beam.

It is preferred that the profiled metal sheeting be profiled steel sheeting.

It is preferred that the beam be supported at each end.

The beam may be supported also at one or more locations along the length of the beam.

The beam may be an internal beam or an edge beam.

It is preferred that there be a plurality of shear connectors.

It is preferred that the shear connectors be headed studs.

The shear connectors may be of any other suitable form such as a structural bolts or channels or shot-fired connectors.

The shear connectors may be arranged in a straight line along the length of the beam or may be in a staggered arrangement along the length with successive shear connectors positioned transversely to the preceding connector.

There may be more than one shear connector at each location along the length of the beam. For example, the shear connectors may be arranged in pairs along the length of the beam.

It is preferred that there be a minimum spacing between the shear connectors along the length of the beam of at least 5 times the diameter of the shear connectors.

It is preferred that the spacing between the shear connectors along the length of the beam be no more than 7.5 times the height of the shear connectors above the top of the concrete ribs. This maximum spacing avoids having to use a reinforcing component of the type described in Australian patent application 69998/01 in the name of the applicant in the composite beam.

In a situation in which the composite beam includes a composite slab rather than a solid slab and the

composite slab includes profiled metal sheeting, the top of the concrete ribs is taken to be the top of the adjacent metal ribs.

In one arrangement it is preferred that the reinforcing component be a flat sheet of welded wire mesh that includes a rectangular array of parallel line wires and cross wires welded together at the intersections of the wires.

The present invention is not limited to the arrangement described in the preceding paragraph and extends, by way of example, to mesh formed from line wires and cross wires that are welded together at wire intersections and has line wires that have a zig-zag shape along at least part of the length of the line wires.

The present invention is described further by way of example with reference to the accompanying drawings of which:

Figure 1 is a perspective view which illustrates, in simplified form, an embodiment of a composite beam (without a layer of concrete that forms part of the beam) in accordance with the present invention;

Figure 2 is an end elevation of the composite beam shown in Figure 1 (with the layer of concrete illustrated in the Figure) in the direction of the arrow A in Figure 1;

Figure 3 is a perspective view of the reinforcing component of the embodiment of the composite beam in accordance with the present invention that is shown in Figures 1 and 2;

Figure 4 is a graph of connector shear force

versus longitudinal slip produced in research work carried out by the applicant on a composite beam in accordance with the present invention of the general type shown in Figures 1 to 3;

Figure 5 is an end elevation similar to that of Figure 2 illustrating a specific form of the embodiment of the composite beam shown in Figures 1 to 3; and

Figure 6 is an end elevation similar to that of Figures 2 and 5 illustrating another embodiment of a composite beam in accordance with the present invention.

The embodiment of the composite beam 3 in accordance with the present invention that is shown in Figures 1 to 3 is in a simplified form to illustrate the composite beam 3 more clearly.

With reference to Figures 1 and 2, the composite beam 3 includes:

(a) a horizontally extending hot-rolled or fabricated steel beam 5 which is supported at each end and at at least one location along the length of the beam so that the beam extends across multiple spans between the beam end supports;

(b) a composite slab including:

(i) profiled steel sheeting 7 in contact with a top flange 9 of the steel beam 5, the sheeting 7 including a plurality of parallel steel ribs 11 separated by pans 13 and positioned so that the steel ribs 11 extend in a direction that is parallel to the

longitudinal axis of the beam 5; and

(ii) a layer 29 of concrete cast on the sheeting 7 and having an upper surface 31 (shown in Figure 2 only), whereby the metal pans and the angled sides of the steel ribs define outer surfaces of concrete ribs 21 and the remainder of the concrete layer 29 defines a slab section of the composite slab;

(c) a plurality of pairs of shear connectors 15 in the form of headed studs that extend through the particular concrete rib 21 shown in Figures 1 and 2 that is positioned on the beam 5 and are welded to the top flange 9 of the beam 5 at spaced intervals along the length of the beam 5; and

(d) a reinforcing component generally identified by the numeral 19 embedded in the concrete slab in the concrete rib 21 in which the shear connectors 15 are positioned for preventing lateral rib punch-through failure of the composite beam 3.

The beam 5, the shear connectors 15, and the composite slab may be of any suitable dimensions and construction. Typically, the shear connectors 15 are spaced longitudinally apart by 100-300mm and transversely apart by 60-100mm. Typically, the composite slab has a thickness of at least 120mm.

In addition, whilst the profiled steel sheeting 7 shown in Figures 1 and 2 has a trapezoidal profile, the sheeting 7 may be dovetail or of any other suitable shape

with open steel ribs.

The reinforcing component 19 shown in Figures 1 to 3 is in the form of a steel mesh that is formed from line wires 41 and cross wires 45 that are welded together at the intersections of the wires to form a generally rectangular array.

The line wires 41 and the cross wires 45 may be the same or different diameters, depending on the circumstances.

The mesh is positioned so that the line wires 41 extend in the longitudinal direction of the concrete ribs 21 and the cross-wires 45 extend transversely to the concrete ribs 21.

In addition, the mesh is positioned within the concrete rib 21 so that it is below the top of the concrete ribs 21, ie below the tops of adjacent steel ribs 11, and more particularly in the embodiment shown in Figures 1 to 3 is approximately midway between the base of the pan 13 and the tops of the adjacent ribs 11.

As is indicated above, the applicant has carried out research work on a portion of a composite beam of the type shown in Figures 1 to 3 on an experimental push-out rig of the applicant.

Figure 4 is a graph of connector shear force versus longitudinal slip produced in the research work. The applicant determined in comparative test work that the use of the reinforcing component 19 produced a 64% increase in the strength of the shear connector of the composite beam and also an increase in ductility of the composite beam.

Figure 5 illustrates a specific form of the embodiment of the composite beam shown in Figures 1 to 3 designed by the applicant for a specific application.

Figure 5 indicates specific dimensions of the composite beam and specific design information for the beam.

It is noted that design of the embodiment of the composite beam shown in Figures 1 to 3 constructed using grade 500 steel can be based on the information in Table 1 below.

Stud Longitudinal Spacing s_c (mm)	Cross Wire Diameter (mm)	Cross Wire Spacing (mm)	Line Wire Diameter (mm)	Line Wire Spacing (mm)
≤ 150	9.5	75	7.6	150
> 150	9.5	150	7.6	150

Figure 6 illustrates another embodiment of a composite beam 3 in accordance with the invention.

The composite beam 3 has the same basic components as the embodiment of the composite beam shown in Figures 1 to 3 and 5 and the same reference numerals are used to describe the same components.

The reinforcing component 19 also includes a plurality of spaced apart additional reinforcing elements 51.

The additional reinforcing elements 51 are in the form of cranked handlebar-shaped bars that are tied to the cross wires 45 and extend from the rib 21 into the adjoining section of the slab section of the concrete layer 29 to prevent delamination of the slab at ultimate load.

Figure 6 illustrates a specific form of the embodiment designed for a specific application.

In any given situation the number of handlebars can be determined having regard to factors such as the compressive strength grade of the concrete and the longitudinal spacing of the shear connectors.

Many modifications may be made to the preferred embodiments of the present invention as described above without departing from the spirit and scope of the present invention.

By way of example, whilst the embodiment of the composite beam shown in Figures 1-3 include pairs of shear connectors 15 along the length of the beams 5, the present invention is not limited to this arrangement and extends to any suitable arrangements such as arrangements in which there are single rather than pairs of shear connectors. Such alternative arrangements are shown in Figures 5 and 6.

Furthermore, whilst the embodiments are arrangements in which the concrete ribs 21 are parallel to the longitudinal axis of the beam 5, the present invention is not so limited and extends to arrangements in which the concrete ribs 21 and the longitudinal axis describe an acute angle of 15° or less.

Furthermore, whilst the embodiments are arrangements which include a composite slab, the present invention is not so limited and extends to arrangements which include solid concrete slabs.

Furthermore, whilst the embodiments are arrangements which include a concrete rib in which the shear connectors 15 are embedded that is defined by a pan

13 and adjacent steel ribs 11 of a single profiled steel sheet, the present invention is not so limited and extends to arrangements in which concrete ribs containing embedded shear connectors are defined by edge pans and ribs of adjacent split profiled steel sheets.

Furthermore, whilst the embodiment shown in Figure 6 describes that the cranked handlebar-shaped bars are tied to the cross wires 45, the present invention is not so limited and extends to arrangements in which the additional reinforcing elements 51 are an integrally formed part of the reinforcing component 19.